Chapter 3
Waterstops and Other Preformed Joint Materials

3-1. General

This manual is primarily concerned with preformed joint materials as obtained from manufacturers. The material differs from the field-molded type of joint sealants because the material configuration is predetermined by design for a known or fixed application or condition. Preformed joint materials are divided into two classes, rigid and flexible. The flexible class of joint material is the most prevalent of the preformed joint materials used and the primary topic of this manual. This manual covers aspects of the rigid class but only to a limited degree.

3-2. Waterstops

a. General. Waterstop is a form of preformed joint material, metallic or nonmetallic, designed to stop the flow or migration of water through open joints. Waterstops may be used in many different types of concrete structures but are primarily used in the monolith joints of hydraulic concrete structures such as navigation locks, dams, floodwalls, and control structures to stop the passage of water and waterborne matter through the joint.

b. Material. Waterstops may be either metallic or nonmetallic. Metallic waterstops are rigid; made from steel, copper, bronze, or lead. Metallic waterstops may be used in large dams and heavy construction projects where strength rather than flexibility is needed. Nonmetallic waterstops are usually composed of natural rubber; synthetic rubbers such as butyl rubber, neoprene, styrene butadiene rubber, and nitrile butadiene rubber; and polyvinyl chloride. Nonmetallic waterstops provide flexibility rather than strength and must possess good extensibility, good recovery, chemical resistance, and fatigue resistance. Some nonmetallic waterstops are thermoplastic in that they can be easily spliced together at the jobsite or configured for special joints.

c. Types. Waterstops are shaped for particular applications. Most metallic waterstops are normally flat but may be preshaped and folded in “Z” and “M” cross-sectional shapes to accommodate unique configurations for special applications. Lead and bronze waterstops are more ductile than the other metallic types and can be shaped more readily. Stainless steel and copper waterstops are resistant to corrosion. Copper waterstops, specified at 0.686 mm (0.0270 in.), should ensure a suitable material. Where steel is desired, 0.925-mm (0.0375-in.) stainless steel should be specified for protection against corrosion. Stainless steel shall be low in carbon and stabilized with columbium or titanium to facilitate welding and to retain corrosion resistance after welding. Metallic waterstops are fabricated to specifications only when required for individual projects and structures. The thickness of a metallic waterstop represents a compromise between flexibility and susceptibility to damage rather than hydrostatic pressure considerations. Nonmetallic waterstops which include butyl rubber, neoprene, polyvinyl chloride, butadiene rubber, and natural rubber are specially shaped to permit a mechanical interlock between the concrete and the waterstop. The rubber waterstops possess high extensibility and high resistance to water and most chemicals and may also be formulated for fast recovery and fatigue resistant. Although the polyvinyl chloride waterstop is not as elastic as rubber, slower in recovery, and more susceptible to oils and some chemicals, it is still the most prevalent of the nonmetallic type. Being thermoplastic, PVC waterstops provide the great advantage of easily being spliced onsite and configured for intersections and directional changes of the joint. Specifications for materials used as waterstops will conform to those set forth in Civil Works Construction Guide Specification CW-03150, which cites CRD-C 513 for rubber and CRD-C 572[1] for polyvinyl chloride waterstops.

(1) Nonmetallic waterstops are manufactured in a wide variety of shapes as illustrated in Figure 3-1. The four most commonly used are the following:

(a) Flat waterstops normally have several rows of ribs along the length of the flanges to provide a better mechanical bond or interlock in the concrete.

(b) Dumbbell-shaped waterstops have solid-core bulbs along the two lengthwise edges to provide a better mechanical bond or interlock in the concrete. These dumbbells also serve as a mechanical seal to resist the flow of water or waterborne materials when embedded in the concrete. The flat waterstop is also available in a split configuration for forming considerations. With the split waterstops, the forms do not require openings for the waterstops to protrude through and are glued back together after removing the forms.

[1] Test methods cited in this manner are from the *Handbook of Concrete and Cement* (U.S. Army Engineer Waterways Experiment Station (USAEWES) 1949).

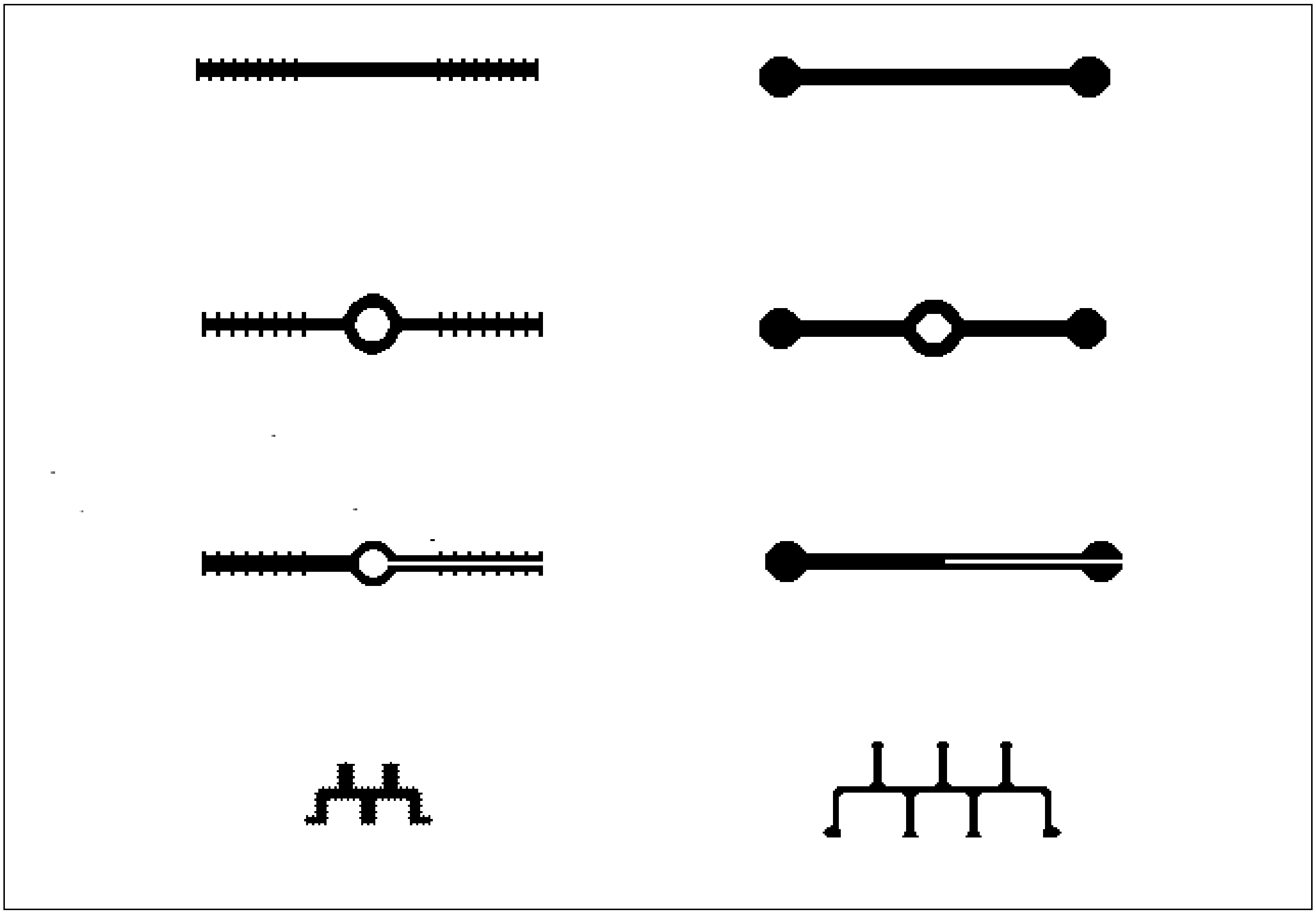


Figure 3-1. Various types and shapes of nonmetallic waterstops

(c) Centerbulb waterstops may be in combination with the flat or the dumbbell-shaped configuration for greater versatility. The centerbulb is hollow, allowing for a wider range of movement in the transverse, lateral, or shear directions and also provides for a greater amount of movement without excessively stretching the material. The split waterstop configuration is also available in the centerbulb type.

(d) Labyrinth-shaped waterstops are shaped to lie within nonmoving joints and not through the joint. They usually have numerous rows of ribs on all the surfaces for greater bond and seal in the concrete; others have bulbs similar to the dumbbell concept.

(2) Dimensional and size requirements of waterstops depend on the joint, its location, hydrostatic pressure, and the amount of movement expected. Most of the basic-shaped nonmetallic waterstops are available as an off-the-shelf item from numerous manufacturers and suppliers. Nonmetallic waterstops are fabricated to specifications and to specific applications and not particularly to individual projects or structures. Table 3-1 lists the four basic shapes of nonmetallic waterstops and their nominal stock dimensions. Nonroutine and unique-shaped waterstops for special applications require special fabrication processes and dies.

d. Applications. Waterstops are used in containers or reservoirs that may be subjected to fluid pressure. Structures may be of a fluid retaining or fluid excluding nature. These include dams, locks, floodwalls, tanks, canal linings, pipelines, swimming pools, floors and walls of underground structures, and any concrete structure possessing contraction and expansion joints.

(1) The most common application of metallic waterstops is the use of flat steel waterstops in the horizontal joints of intake structures, because of the minimal movement in these joints.

Table 3-1
Shapes and Dimensions of Stock Nonmetallic Waterstops

Shape	Waterstop Flange Thickness	Overall Waterstop Width	Bulb Diameter
(a) Flat	3.2 to 12.5 mm (1/8 to 1/2 in.)	100 to 225 mm (4 to 9 in.)	
(b) Dumbbell	4.7 to 9.5 mm (3/16 to 3/8 in.)	100 to 300 mm (4 to 12 in.)	9.5 to 25 mm (3/8 to 1 in.)
(c) Centerbulb	3.2 to 12.5 mm (1/8 to 1/2 in.)	100 to 300 mm (4 to 12 in.)	6 to 70 mm (1/4 to 2-3/4 in.)
(d) Labyrinth	4.7 to 6.3 mm (3/16 to 1/4 in.)	82 to 156 mm (3-1/4 to 6-1/4 in.)	

(2) Nonmetallic waterstops are generally used across an open expansion or contraction joint where a predetermined amount of movement is expected. Flat waterstops may be used in joints where very little lateral movement is expected. Dumbbell-shaped waterstops are also used in joints where small amounts of lateral movement is anticipated. The centerbulb-type waterstop is a universal type of waterstop and may be applied in both expansion and contraction joints where significant amounts of lateral as well as transverse movements is predicted. The labyrinth-shaped waterstop may be used under certain conditions where very little if any differential joint movement will occur and under very little hydrostatic pressures.

(3) Nonmetallic waterstops, especially PVC waterstops, are easily spliced to form different configurations. These configurations allow the waterstops to be placed in a variety of positions, such as around corners, at the intersection of complex construction, around columns, and other situations. Many manufacturers supply the difficult and special configurations as premade splices, which allows the contractor to perform the simple butt splice. The butt splice is much easier to perform than are the ‘L’, ‘T’, or the ‘+’ splices. The butt splice is the butting together the ends of the same type waterstop in alignment with bulbs, flanges, and ribs. The butting ends are melted with a heating device and simply butted together. Upon cooling, the splice should be cleaned of excess material and inspected for bubbles, cracks, voids, misalignment, and burned material in the spliced area.

e. Construction. Waterstops are embedded in the concrete. Unlike most joint sealants that require installation after construction, waterstops are placed in the forms prior to concreting. The concrete is placed in the form and is molded to conform to the shape of the waterstop.

(1) Metallic waterstops form an adhesive bond between the metallic waterstop material and the concrete. The superior strength of flat steel waterstop over other metallic types provides resistance to the increased potential for damage during waterstop installation and subsequent construction operations during placement of the next concrete lift. A typical installation would use a steel plate 200 to 225 mm (8 to 9 in.) wide and 3 to 4.7 mm (1/8- to 3/16-in.) thick.

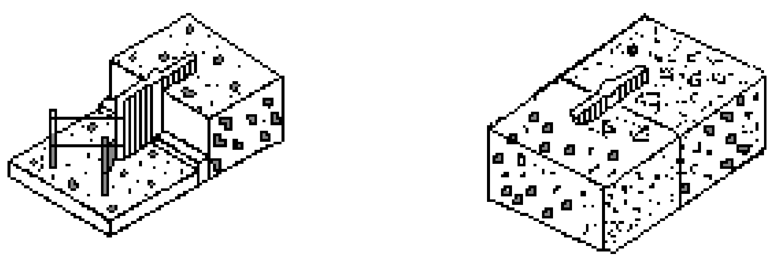
(2) However, with nonmetallic waterstops that are made from rubber or polyvinyl chloride materials, a mechanical bond or interlock is formed with the ribs or bulbs of the waterstop rather than a chemical or adhesive bond. Currently, special repair techniques are being investigated that allow waterstops to be installed in hardened concrete. (See section 8-2 of EM 1110-2-2002 for current methods of repair of waterstop failures).

(3) Waterstops shall be stored in areas protected from the environment, dirt, oils, chemicals, debris, and physical damage. The waterstop shall be protected during handling, installation, and fabrication of splices. Damaged waterstops shall be removed from service and properly disposed of. All nonmetallic and flexible metallic waterstops shall be uncoiled approximately 24 hr prior to installation or splicing.

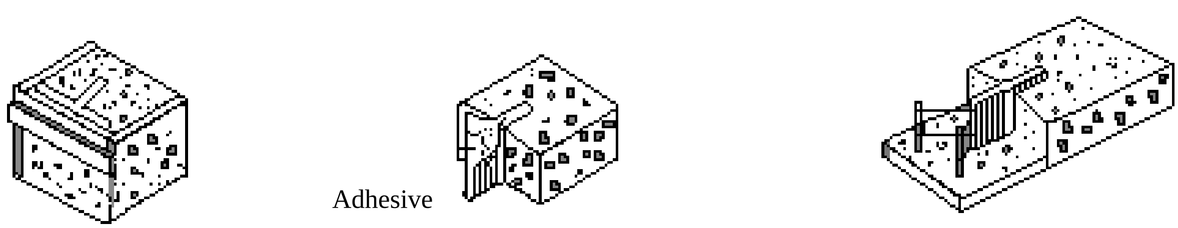
f. Installation. Metallic waterstops are securely installed in the formwork prior to concreting. Special care in handling is required for all waterstops to avoid tearing or bending the material. Waterstops are installed in, through, and in some situations against the formwork as in the case of the nonmetallic split waterstop. Nonmetallic dumbbell- and centerbulb-type waterstops are available in a split configuration as shown in Figure 3-1. Split configuration waterstops provide for easier installation into forms and much easier erection of the forms as shown in Figure 3-2. One flange of the split waterstop is split to allow the flange to open and be fastened flush to the inside of the formwork; this eliminates the use of split formwork, which is considered difficult to construct. With split formwork, the installation technique requires the form to be open, thus allowing insertion of the waterstop through the form. The exercise of particular care in the installation of waterstops in accordance with the provisions set forth in Civil Works Guide Specification CW-03150 should be emphasized. Adequate support against displacement, especially when placing large nominal maximum-size aggregate concrete, should be stressed to ensure correct positioning and embedment of waterstops. The exposed waterstop shall be cleaned of laitance, form oil, dirt, and excess concrete prior to the second placement.

3-3. Preformed Compression Seals

a. General. Preformed compression seals are a form of preformed joint material that are compartmentalized or cellular in its internal structure. The preformed compression seal functions as a joint material when compressed and installed between two concrete surfaces or two armored concrete surfaces as in pavements and bridge decks. The preformed compression seal is designed with the compressible cellular structure as shown in Figure 3-3 to be compressed and inserted into a preexisting joint. The introduction of joints in a concrete structure creates openings which must be sealed to prevent the intrusion or passage of water, hard particles such as sand particles and trash, or unwanted substances such as jet fuels and other chemicals into the joint.



In conventional construction, the installation of nonmetallic waterstops requires the formwork to be split to accommodate the waterstop flange protruding through the formwork.



With split-flange, nonmetallic waterstops, the installation of the waterstops requires no special formwork, the forms are flush with the concrete. After the formwork has been stripped away, the split flanges are bonded together prior to the next concrete placement.

Figure 3-2. Nonmetallic waterstops may be installed by the split form method or by using split-flange waterstops

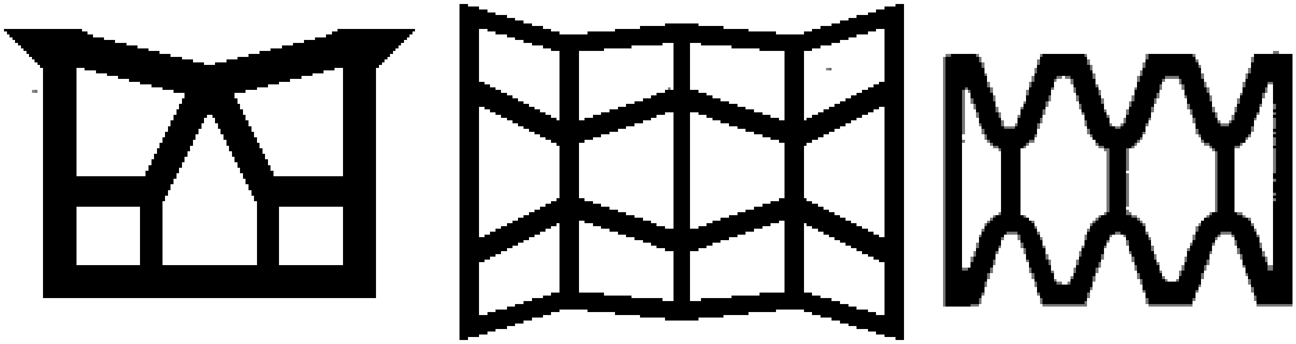


Figure 3-3. Preformed compression seals are compartmentalized in their internal structure for compressible behavior. Shown are three of the several types and shapes of preformed compression seals available as stock materials

b. Materials. Preformed compression seals are elongated units that have been extruded and vulcanized from neoprene and polychloroprene rubber compounds and polyurethane. These elastomeric compounds provide high resistance to ozone deterioration, resistance to fuel and oil, quick recovery from high and low temperatures, and great flexibility. The effective sealing of joints is more complex than merely filling a gap with a flexible, low-permeability material. Preformed compression seals require a lubricant for installation. The lubricant also acts as an adhesive in bonding the compression seals to the walls of the joints.

c. Types. The preformed compression seal is the most common of the preformed sealants. Basically, there are two main types of preformed joint sealants: the compression seal and the tension-compression seal. As implied by the group names, the compression seals are always in compression as shown in Figure 3-4 and the tension-compression seals may be in compression or tension when they are in a working joint. Compression-seal manufacturers produce generally three basic shapes of the preformed sealants. The internal webbing of the three shapes are similar, but the top surface of the preformed sealant are different. The most common surface is the ‘V’ shaped; it also has the widest range of sizes. The other two surfaces are the ‘W’ shape and the wave shape (Table 3-2).

d. Function. The shape of the joint and the anticipated movement, as well as the physical properties of the joint material, must be considered. The preformed compression seals must also protect against the adverse effects of severe and cyclical weather while preserving the ability of the joint to function as designed. In most concrete structures, whether hydraulic or nonhydraulic, the concrete-to-concrete joint, such as an expansion or contraction joint, must be sealed to prevent damage to the joints. Construction joints are an exception in the use of preformed compression seals. To perform satisfactorily, the preformed compression seal must have certain basic properties:

The preformed compression seal must:

(a) have adequately low permeability,

(b) be flexible to deform to accommodate the range of movement,

(c) be able to recover to its original shape and retain its properties,

(d) remain in contact with joint faces at all times,

(e) be durable internally throughout its webbing design,

(f) remain firm and stable at high temperatures,

(g) remain flexible and soft at low temperatures,

(h) resist the affects of aging, weathering, and other environmental conditions, and

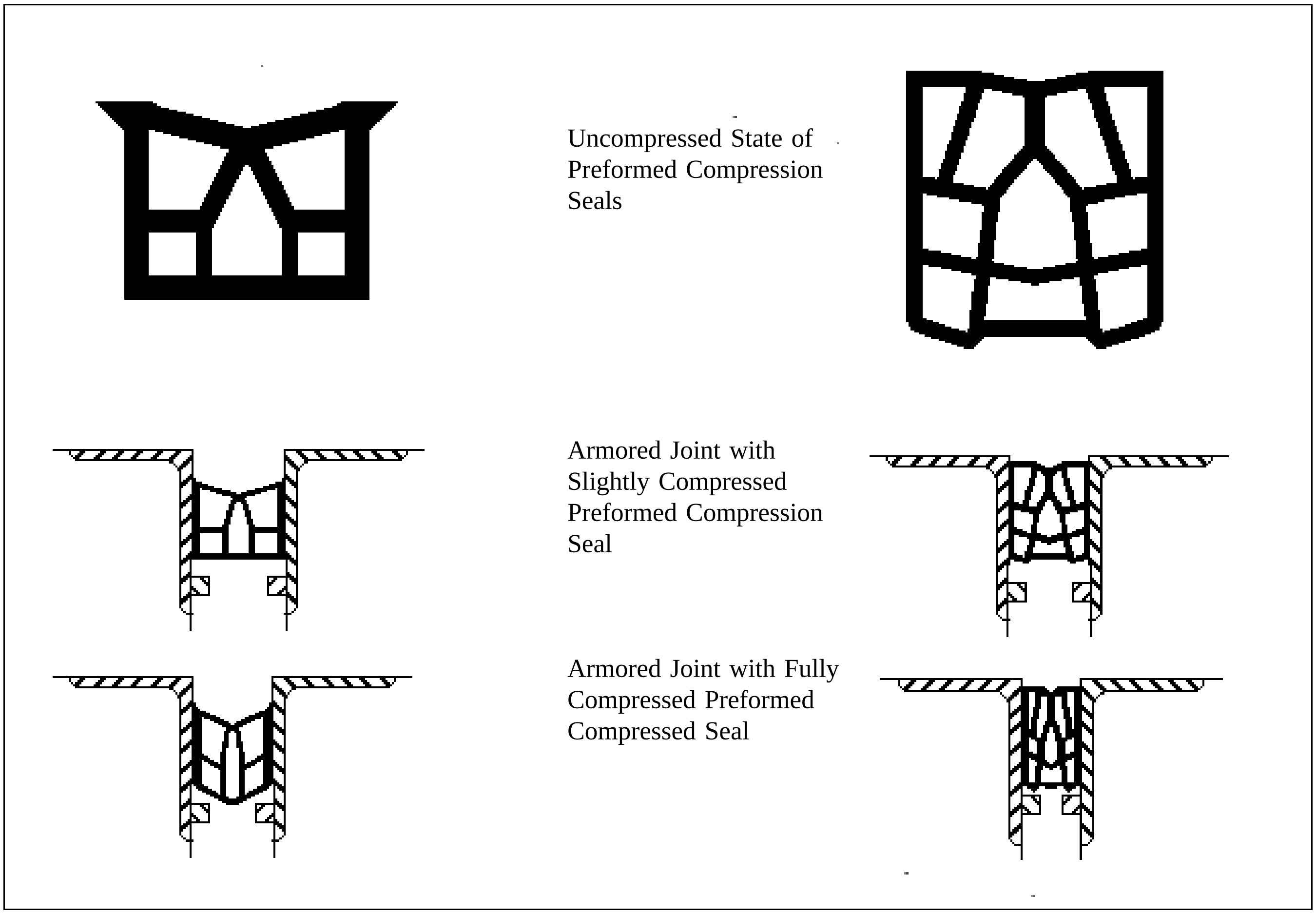


Figure 3-4. Preformed compression seals are compressed and inserted into the joint and remain in a compressed state. As the concrete expands and contracts, the compression seals remain in the compressed state

Table 3-2
Dimensions of Stock Compression Seals

Shape of Top	Nominal Width	Nominal Height	Max. Movement
(a) V	8 to 150 mm (5/16 to 6 in.)	16 to 141 mm (5/8 to 5-5/8 in.)	3.5 to 82.5 mm (0.14 to 3.25 in.)
(b) W	31.5 to 150 mm (1-1/4 to 6 in.)	31.5 to 141 mm (1-1/4 to 5-5/8 in.)	12.5 to 75 mm (0.5 to 3 in.)
(c) Wave	50 to 150 mm (2 to 6 in.)	37.5 to 90 mm (1-1/2 to 3-1/2 in.)	18 to 75 mm (0.7 to 3 in.)

(i) be resistant to chemicals, oils, and fuels.

The references to high and low temperatures given above reflect the actual temperature of the concrete surface being joined or sealed by the joint material which in turn determines the magnitude of joint movements and consequent joint material performance. This range may vary from the ambient up to 66 °C (150 °F) where concrete is in constant contact with a material having a rapid temperature change rate, down to a very small range in structures below ground or underwater.

e. Application. Preformed compression seals are used in all types of structures, those under a slight fluid pressure and those that are not under any fluid pressure but require hard particles to be prevented from entering or passing through the joints. These include buildings, bridge decks, storage bins, retaining walls, roof decks, walkways, highways, airfield, floors, walls, and tunnels. They also include fluid retaining and excluding structures, but mostly low fluid pressure structures.

f. Construction. Preformed compression seals may be used in repair work as well as in new construction. New structures may be constructed with prepositioned joints cast in place or the structure may be cast monolithically and cut or sawed in specified intervals or locations for installing joint sealants. Repair techniques may warrant replacing deteriorated joint material or it may be required to correct a deficiency in the concrete such as cracks. The cracks may have opened to relieve the concrete from internal stresses. These cracks may be converted to joints by cutting or sawing through the crack, cleaning and removing the deteriorated concrete, and repairing the surfaces of the joint to a specified width and depth. The joint must be uniform in width, straight, smooth, and clean to provide uniform contact to both surfaces.

g. Installation. Preformed compression seals may be installed in preexisting joints by several methods ranging from manual installation to fully automated systems that lubricate the sealant as it installs the compression seal into the joint. The manual procedure requires compressing the preformed compression seal to a width slightly narrower than the joint opening and exerting pressure along the outer edge of the compression seal to insert the joint material into the opening. Other manual procedures require special tools for alignment and exerting pressure both laterally and longitudinally along the compression seal. The special tools are primarily for larger and wider preformed compression seals that require more force and pressure to compress the joint material. The automated units are primarily for pavements. All installation methods, procedures, and equipment require the use of a lubricant or an adhesive to properly install the preformed compression seal. The lubricant facilitates the installation of the joint material into the joint and the adhesive bonds the joint material to the walls of the joint.

3.4 Miscellaneous Sealants

a. General. There are a number of other preformed joint materials used in hydraulic and nonhydraulic structures. These include tension-compression seals, gate seals, gaskets, and tapes. The tension-compression seals are used in similar conditions as the strict compression seal in pavements and bridge decks, except the design incorporates steel plates and fixed anchorages to support heavy loads and traffic on the bearing surface. The gate seals are used in hydraulic structures as a means of sealing the flow of water through the joints around gates and bulkheads including: vertical lift, tainter, head, flood, spillway, sluice, emergency, service, slide, caterpillar, wheel, sector, and miter gates. Gaskets and tapes are used primarily in pipes and walls.

b. Tension-compression seals. Tension-compression seals are designed for heavy traffic areas where considerable movement is anticipated. These joint materials consist of flexible elastomeric materials with steel bearing plates encased in the material to increase the durability of the seal in traffic. Other designs of tension-compression seals incorporate the steel plates onto the riding surface of the sealant to significantly increase the wear resistance caused by heavy traffic, studded tires, snowplowing, and abrasives. The tension-compression seals are anchored to the concrete faces to provide the tensile component of the joint material. Grooves are formed in the sealants to permit greater changes in joint movements, up to 330 mm (13 in.) in some bridge decks.

c. Gate seals. Gate seals are used to stop leakage at the joint area between the gate and the sill. Gate seals are designed with numerous shapes for different applications. The two most commonly used are the 'J' and 'L' types as described by several manufacturers. Gate seals are made of rubber because of its ability to form a tight seal on contact with any reasonably smooth surface. The gate seals are mounted to the upstream side of the gates; this allows the water pressure to increase the contact pressure of the seal to the gate. However, with the gates in the open position, the gate seals must be securely fastened to prevent water from flowing underneath them. Placement details must be carefully worked out to prevent excessive wear of the rubber gate seal during normal usage. Only very light contact is needed between the gate seal and the sill when there is a no water load contact, otherwise excessive wear could result in those dry situations. The gate seal may be spliced at the transition from side seals to bottom seals.

d. Gaskets and tapes. In nonhydraulic situations, wall joints may be sealed using gaskets and tapes. Gaskets are also used in joints between pipes and service lines. Gaskets and tapes generally are composed of rubber or polyvinyl chloride. Their sealing action is obtained by compressing the joint material between the joint faces similar to the compression seals or because of the pressure sensitive nature of some butyl compounds, the joint material adheres to the surface of the joint.